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13. ABSTRACT *(Maximum 200 words)*
Because of detailed evaluation of the quality of our LHPG fibers by Dr. D. Evans of the AFRL, we were able to pinpoint the cause of the majority of the defects in our Laser Heated Pedestal Growth (LHPG) fibers. The principal defects found in our materials lay in the non-uniformity of the diameter of our fibers and in the fact that the fibers contained cracks and striations, especially the thinner fibers, which adversely affect optical transmission. In addition, the fibers were grown in air and showed a dark coloration which required additional treatment and annealing to render transparent. In the course of this period of the grant, we designed and constructed a new LHPG pulling system which remedied the causes of the problems mentioned above. The new LHPG system is totally enclosed in a chamber which allows regulation and control of the atmosphere and temperature in which the fibers are pulled. In addition to air, the system can now accommodate admixtures of nitrogen, oxygen and hydrogen as well a partial vacuum. Fibers of LiNbO3 grown in the new system under an oxygen atmosphere, for example, no longer show any coloration. We believe the controlled atmosphere also aids in reducing crystalline flaws.

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FINAL REPORT

"GROWTH AND TAILORING OF PHOTOREFRACTIVE FIBERS USING THE LASER HEATED PEDESTAL GROWTH METHOD"

Grant Number: F49620-00-1-0134

Period of Report: September 1, 2001 to August 31, 2002

AFOSR Program Manager: Dr. Charles Lee

Principal Investigator: William M. Yen

Institution: University of Georgia, Department of Physics and Astronomy
Athens, GA 30602

SECTION A: SUMMARY OF PROGRESS

Because of detailed evaluation of the quality of our LHPG fibers by Dr. D. Evans of the AFRL, we were able to pinpoint the cause of the majority of the defects in our Laser Heated Pedestal Growth (LHPG) fibers. The principal defects found in our materials lay in the non-uniformity of the diameter of our fibers and in the fact that the fibers contained cracks and striations, especially the thinner fibers, which adversely affect optical transmission. In addition, the fibers were grown in air and showed a dark coloration which required additional treatment and annealing to render transparent.

The physical imperfections of our fibers arose because of small mechanical instabilities in our LHPG system. These consisted of transmitted vibrations from motors and pumps and from occasional random variations in the pulling speed of the stepping motor drive. The coloration of the fibers was traced to the reduction of Nb^{5+} to Nb^{4+} because the fibers were grown in open air.

In the course of this period of the grant, we designed and constructed a new LHPG pulling system which remedied the causes of the problems mentioned above. The new LHPG system is totally enclosed in a chamber which allows regulation and control of the atmosphere and temperature in which the fibers are pulled. In addition to air, the system can now accommodate admixtures of nitrogen, oxygen and hydrogen as well as a partial vacuum. Fibers of $LiNbO_3$ grown in the new system under an oxygen atmosphere, for example, no longer show any coloration. We believe the controlled atmosphere also aids in reducing crystalline flaws.

The redesigned mechanical system isolates the pulling mechanisms from the optics as well as from the enclosing chamber. The input Reflexicon mirror and the focusing FIR heating mirror are now locked in an optimized position as are the

feeding and pulling mechanisms. The stepping motors have been replaced with micro steppers capable of pulling and feeding with rates as slow as 50nm/min. Again, using this system, fibers grown show a much improved uniformity of diameter and a noticeable reduction in imperfections and scattering centers. Evaluation at the AFRL showed that the transmissivity of the as-grown fibers increased from 20% to 60-75%; additionally, we have been able to pull thinner fibers than before.

We have been able to routinely control the stoichiometry of the $LiNbO_3$ fibers produced by changing the lithium content of ceramic starting stock material. We had also developed a method with which to monitor the valence of the Fe ions intentional or unintentionally doped into LNO crystals; by properly controlling the growth atmosphere, we have been able to accurately introduce the proper Fe^{3+} doping level into the LHPG fibers we have delivered. We have also made some trial runs at growing alternative photorefractive materials such as $KNbO_3$ and $BaSrTi_2O_3$; the results have been encouraging and we are in a position to provide samples of these materials should the need arise.

Up to 25 fibers of LNO drawn from our new system have been delivered to various collaborators of this effort. These fibers were as long as 30mm in length and in the vicinity of 100-200 μm in diameter. Variations in diameter were down to 5% or so.

The origin of the noise in the nonlinear photorefractive signals obtained in mixing experiments in LNO had been traced to electric charge build up on the surface of the fiber and bulk materials. We have been able to demonstrate (Basun) that by providing a conducting path to ground, the charge and hence the noise induced through this source can be greatly reduced. These results are being prepared for publication.

We have also continued to pursue the possibilities of providing clad and/or tapered fibers of LNO and other photorefractives for additional possible applications.

SECTION B: PERSONNEL SUPPORTED

1). Principal Investigator:

William M. Yen

2). Post Doctoral Associates

Lizhu Lu
Dongdong Jia, for period June –October, 2002

3). Other Associated Researchers

Sergei Basun

G.F. Imbusch

SECTION C: PUBLICATION AND PRESENTATIONS UNDER AFOSR SUPPORT:

1). Refereed Journal:

D.R. Evans, M.A. Saleh, T.J. Bunning, S. Guha, L.Lu, R.S. Meltzer and W.M. Yen, Contra-direction two beam coupling using a single input beam in an iron lithium niobate fiber, Appl. Opt. (to be published, 2002).

S.A. Basun, D.R. Evans, J.O. Barnes, T.J. Bunning, S. Guha, G. Cook and R.S. Meltzer, Optical Spectroscopy of Fe^{2+} and Fe^{3+} ions in $LiNbO_3$, J. Appl. Phys. 92 (December issue)

M.M. Chirila, N. Y. Garces, L.E. Halliburton, D.E. Evans, S.A. Basun, R.S. Meltzer, W.M. Yen, S.A. Rutkowski, D. Shumov and J.S. Cahill, Thermoluminescence study of stoichiometric $LiNbO_3$ crystals, J. Appl. Phys. 92, 1221-26 (2002)

2). Proceedings Volumes:

D.R. Evans, T.P. Pottenger, M.A. Saleh, S.A. Basun, G.R. Landis, T.J. Bunning and S. Guha, Investigation of photorefractive nonlinear optical properties of iron-doped lithium niobate in bulk and fiber configurations, Proc. SPIE 4462, 111-124 (2001)

M.A. Saleh, D.R. Evans, R.N. Shariff, T.P. Pottenger, L. Lu, R.S. Meltzer, W.M. Yen, T.J. Bunning and S. Guha, Contra-directional two-wave mixing in bulk and multimode fibers of iron-doped lithium niobate, Proc SPIE 4459, 71-75 (2001)

3). Conference Presentations:

D.R. Evans, T.J. Bunning, S. Guha, S.A. Basun, R.S. Meltzer, Investigation of thermoluminescence and the pyroelectric effect in $LiNbO_3$: Fe, APS March Meeting, Indianapolis (2002)

D.R. Evans, J.O. Barnes, T.J. Bunning, S. Guha, S.A. Basun, G. Cook and R.S. Meltzer, Determining concentrations of divalent and trivalent iron in lithium niobate using optical absorption spectroscopy, APS March Meeting, Indianapolis (2002)

D.R. Evans, M.A. Saleh, A.S. Allen, T.P. Pottenger, T.J. Bunning, S. Guha, S.A. Basun and G. Cook, Elimination of a photovoltaic-induced fast instability in photorefractive iron-doped lithium niobate crystals, APS March Meeting, Indianapolis (2002)

D.R. Evans, M.A. Saleh, T.P. Pottenger, T.J. Bunning, S. Guha and S.A. Basun, Eliminating photorefractive grating instabilities during contra-directional two-wave mixing in iron-doped lithium niobate, CLEO, Long Beach (May 2002)

G.F. Imbusch

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